TOOLS FOR SECURING CONNECTORS USING EXPLOSIVE CHARGES AND METHODS FOR USING THE SAME

Field of the Invention

The present invention relates to tools and methods for using tools and, more particularly, to tools and methods for securing or terminating connectors.

Background of the Invention

Electrical cables often must be terminated or joined (spliced) in various environments, such as underground or overhead. Such cables may be, for example, high voltage electrical distribution or transmission lines. In order to form such connections, a connector may be employed. To install such connectors, it may be necessary to force two members into engagement, typically such that one or both of the members are deformed. Exemplary connectors include a C-shaped sleeve and wedge combination as disclosed in U.S. Patent No. 4,722,189 to Center. In order to install such connectors, it is typically necessary to apply a relatively great force between the wedge and the sleeve. However, the amount of force should not be excessive as this may compromise the formation or integrity of the connection. Because the connections are often formed in dangerous locations (*e.g.*, high above the ground) and with high voltage lines, it is desirable to provide the necessary force in a manner that is convenient and safe under such circumstances.

To provide the application force as discussed above, explosive charge-actuated tools (sometimes referred to as "powder-actuated tools") are commonly used. According to some designs, explosive charge-actuated tools include a tool body, a tool head secured to the tool body, and a ram slidably mounted in the tool

body. In use, the connector components are placed between the ram and the tool head. An explosive charge, typically provided in a cartridge, is exploded in the tool body such that the ram is forced against the connector to thereby force the connector components into secure engagement. The explosion of the charge may generate pressurized gas in the tool body. If not first controllably released, the pressurized gas may harm the user when the user attempts to open the tool body to remove the expended explosive charge cartridge. Thus, tools of this type may provide a mechanism for pre-releasing pressurized gas from the tool body, for example, from a breech chamber that holds the cartridge. Exemplary tools of this type include the AMPACT tool available from Tyco Electronics, Inc. and the tools disclosed in U.S. Patent No. 4,722,189 to Center and in U.S. Patent No. 4,905,603 to McBain. However, such tools may be difficult to operate under some circumstances or may require substantial and frequent maintenance to ensure safe and effective operation.

Summary of the Invention

According to embodiments of the present invention, a tool for securing a connector on a conductor using an explosive charge includes a first tool member and a second tool member movably mounted on the first tool member. A breech chamber is defined in at least one of the first and second tool members. The breech chamber is adapted to receive the explosive charge. A breech opening is defined in at least one of the first and second tool members and communicates with the breech chamber. A drive member is provided. The tool is adapted to forcibly move the drive member responsive to an explosion of the explosive charge in the breech chamber. The second tool member is movable between a closed position, wherein the breech opening is closed, and an open position, wherein the breech opening is open to allow loading and unloading of the explosive charge into and from the breech chamber, by sliding the second tool member relative to the first tool member along a slide axis and additionally pivoting the second tool member relative to the first tool member about a pivot axis transverse to the slide axis.

According to method embodiments of the present invention, a method for using a tool for securing a connector on a conductor using an explosive charge is provided. The tool includes: a first tool member; a second tool member movably mounted on the first tool member; a breech chamber defined in at least one of the

first and second tool members, the breech chamber being adapted to receive the explosive charge; a breech opening defined in at least one of the first and second tool members, the breech opening communicating with the breech chamber; and a drive member. The tool is adapted to forcibly move the drive member responsive to an explosion of the explosive charge in the breech chamber. The method includes sliding the second tool member relative to the first tool member along a slide axis. The second tool member is pivoted relative to the first tool member about a pivot axis transverse to the slide axis such that the second tool member is moved from a closed position, wherein the breech opening is closed, to an open position, wherein the breech opening is open to allow loading and unloading of the explosive charge into and from the breech chamber.

Objects of the present invention will be appreciated by those of ordinary skill in the art from a reading of the figures and the detailed description of the preferred embodiments which follow, such description being merely illustrative of the present invention.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain principles of the invention.

Figure 1 is a perspective view illustrating the formation of a connection using a tool assembly and methods according to embodiments of the present invention;

Figure 2 is a perspective view of a drive assembly forming a part of the tool assembly of the **Figure 1**;

Figure 3 is a front, perspective, exploded view of the drive assembly of **Figure 2**;

Figure 4 is a rear, perspective, exploded view of the drive assembly of **Figure 2**;

Figures 5A and 5B are perspective views of a breech forming a part of the drive assembly of **Figure 2** as viewed from opposed sides thereof;

Figure 6 is a side elevational view of the tool assembly of **Figure 1** and a cartridge for use therewith, wherein the drive assembly is in an open position;

Figure 7 is a side elevational view of the tool assembly of **Figure 1** wherein the drive assembly is in a further position;

Figure 8 is a side elevation view of the tool assembly of **Figure 1** wherein the drive assembly is in a further position;

Figure 9 is a further perspective view of the drive assembly of **Figure 2**;

Figure 10 is a cross-sectional view of the drive assembly of **Figure 2**;

Figure 11 is a cross-sectional view of the drive assembly of **Figure 2** taken along the same line as **Figure 10** and wherein the drive assembly is in a further position; and

Figure 12 is a cross-sectional view of the drive assembly of **Figure 2** taken along the same line as **Figure 10** and wherein the drive assembly in a further position.

Detailed Description of Preferred Embodiments

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

With reference to **Figure 1**, a tool assembly **40** according to embodiments of the present invention is shown therein. The tool assembly **40** may be used to form a connection **5** as shown in **Figure 1**, for example. The connection **5** includes a pair of conductors **7, 9** securely and electrically coupled by a connector **20**. The connector **20** includes a C-shaped sleeve **22** and a wedge **24**. Connectors of this type are well-known to those of skill in the art and will not be described in further detail herein except as needed to describe embodiments of the present invention. Generally, and as described in more detail below, the tool assembly **40** may be used to force or impel the wedge **24** and the sleeve **22** into engagement using an explosive charge **32** (*e.g.*, as provided in a cartridge **30**; see **Figure 11**).

With reference to **Figure 1**, the tool assembly **40** includes an explosively actuated industrial tool **45** and an anvil or tool head **80**. The tool **45** includes a barrel or coupling **50**, a coupling nut **60**, a drive assembly **100** joined to the

coupling **50** by the coupling nut **60**, and a ram **70** slidably mounted in the coupling **50**. With reference to **Figure 6**, the drive assembly **100** includes a breech **102**, an ejector sleeve **130**, and a breech cap assembly **150**. Each of these components will be described in more detail below. The coupling **50**, the coupling nut **60** and the ram **70** are omitted from **Figures 11** and **12** for clarity.

The coupling **50** includes threads **52** (**Figure 10**) on its outer surface. A bore or barrel passage **54** extends through the coupling **50** and communicates with opposed end openings **56** (**Figures 1** and **10**).

The breech **102** has opposed front and rear ends **104A** and **104B**. A breech chamber **106** (**Figure 11**) is defined in the breech **102**, which is generally tubular. The breech chamber **106** communicates with a front breech opening **108A** (**Figure 3**) and a rear breech opening **108B** (**Figure 4**). A coupling thread **110** (**Figure 5A**) is formed on the outer surface of the breech **102** on the front end **104A** thereof. A radially extending coupling set screw bore **112** (**Figure 3**) is also formed on the front end **104A** for securing the breech **102** to the coupling nut **60**. A pair of opposed, axially extending guide channels **114A, 114B** (**Figures 5A** and **5B**) are defined in the outer surface of the breech **102** on opposed sides thereof. A pair of circumferentially extending guide channels **116A** and **116B** (**Figures 5A** and **5B**) are also defined in the outer surface of the breech **102** on opposed sides thereof and intersect the axially extending channels **114A** and **114B**, respectively, adjacent the front end **104A**. A pair of opposed, radially extending screw holes **118** (**Figure 4**) are formed in the rear end **104B**. A recessed end portion **120** and an end flange **122** are also provided on the rear end **104B** (**Figure 4**).

The ejector sleeve **130** is mounted on the recessed end portion **120**. The ejector sleeve defines a front opening **134A** (**Figure 3**), a rear opening **134B** (**Figure 4**) and a bore **132** (**Figure 3**) communicating with each of the openings **134A, 134B**. The rear opening **134B** is defined by a radially inwardly extending, circumferential flange **136** (**Figure 4**). The bore **132** receives the recessed end portion **120** such that the flange **136** surrounds the end flange **122**. Opposed guide screws **140** (**Figures 3** and **10**) extend from the screw holes **118 in** the recessed end portion **120** and are slidably received in opposed axially extending slots **138** (**Figure 3**) defined in the ejector sleeve **130**. Grip ribs **146** (**Figure 6**) are provided on opposed sides of the ejector sleeve **130**. The ejector sleeve **130** further includes a lock pin recess **142** and a support recess **144** (**Figure 4**).

The coupling nut **60** includes a threaded bore **62** (**Figure 10**). The threaded bore **62** is configured to threadedly engage the coupling threads **110** of the breech **102**. The coupling nut **60** serves to secure the coupling **50** to the drive assembly **100**. The coupling **50** is slidable in the coupling nut **60** so as to allow a small gap **78** (see **Figure 10**).

The ram **70** is a generally cylindrical rod having a strike end **72** (**Figure 10**) and an opposed driven end **74** (**Figure 1**). A firing pin **76** (**Figure 10**) projects from the driven end. The ram **70** is slidable in the coupling **50** and the breech **102**.

The breech cap assembly **150** includes a breech cap sleeve **152**, a pin guide housing **170**, a pin guide **180**, a retaining spring **181**, a gas release member or knob **190**, a piercer pin **184**, a stop screw **199**, and a lock pin **179**. The breech cap assembly **150** is movable between a closed position (**Figures 2** and **12**) and an open position (**Figure 6**) as described in more detail below.

The breech cap sleeve **152** is generally tubular and defines an axially extending passage **154** that, in the closed position, surrounds the breech **102** and the ejector **130**. A front opening **154A** (**Figure 3**) and a rear opening **154B** (**Figure 4**) communicate with the passage **154** on either end. Internal threads **156** (**Figure 4**) are formed adjacent the rear opening **154B**. A lock pin guide slot **158** extends axially through the threads **156**. Knurling may be formed on the outer surface of the breech cap sleeve **152** to facilitate gripping. Opposed slots **162**, **164** (**Figure 3**) are defined in the breech cap sleeve **152** adjacent and in communication with the front opening **154A**. The slot **164** is longer than the slot **162**. The slots **162**, **164** define opposed, axially extending arms **166**. Opposed guide projections or tabs **167** extend radially inwardly from respective ones of the arms **166** and into respective ones of the channels **116A**, **116B** when the breech cap assembly **150** is in the closed position. An end groove **168** formed in the breech cap sleeve **152** adjacent the rear end **154B** and is adapted to receive the retaining spring **181**.

With reference to **Figures 3** and **4**, the pin guide housing **170** defines a front opening **174A**, a rear opening **174B**, and a bore **172** communicating with each of the openings **174A**, **174B**. Internal threads **175** are provided in the bore **172**. A knurled flange **176** is provided for manipulating the pin guide housing **170**. A tab **177** extends axially rearwardly from the flange **176**. External threads **178** are formed adjacent the front opening **174A** and are configured to mate with the threads **156** of the breech cap sleeve **152**. Slots are formed in the groove **168** of

the breech cap sleeve **152** to allow the retaining spring **181** to extend therethrough and engage the threads **178**, thereby preventing full withdrawal of the pin guide housing **170** from the breech cap sleeve **152.**

As best seen in **Figures 3** and **10**, the lock pin **179** is mounted on the threads **178** of the pin guide housing **170** such that the threads **178** are received in an intermediate cutout **179A** of the lock pin. A front portion of the lock pin **179** is slidably received in the lock pin guide slot **158** of the breech cap sleeve **152** and, when the breech cap assembly **150** is in the closed position, into the lock pin recess **142** of the ejector sleeve **130**. A rear portion of the lock pin **179** extends rearwardly from the breech cap sleeve **130** and abuts the flange **176** of the pin guide housing **170**.

The pin guide **180** is disposed in the bore **172** of the pin guide housing **170**. External threads on the outer surface of the pin guide **180** mate with the internal threads **175**. An axially extending passage **182** (**Figure 12**) is defined in the pin guide **180**. The piercer pin **184** is slidably received in the passage **182**. According to some embodiments, the pin guide **180** and the pin guide housing **170** may be unitarily formed.

The gas release knob **190** includes an end wall **191**. A flange **193** (which may be knurled) surrounds the end wall **191** for manipulating the gas release knob **190**. The piercer pin **184** is fixed within a pin bore **194** formed in the end wall **191**. A pair of gas release passages **196** formed in the end wall **191** provide fluid communication between the breech chamber **106** and the environment. External threads **197** are formed on the front end of the gas release knob **190** and mate with the threads **178** of the pin guide housing **170**. A threaded stop screw hole **198** extends axially through the flange **193**. The stop screw **199** is mounted in the stop screw hole **198** with a portion **199A** (**Figure 10**) of the stop screw **199** extending axially forward from the flange **193** such that the portion **199A** engages the tab **177** of the pin guide housing **170** upon rotation of the knob **190**. That is, the portion **199A** and the tab **177**, or respective portions thereof, are located at the same positions along the axis **S-S** and the same radial distance from the axis **S-S**.

According to some embodiments, the piercer pin guide **184** and the gas release knob **190** may be unitarily formed. According to some embodiments, the pin guide housing **170** may be omitted. In this case, the piercer pin guide **180** may be secured to or formed as a part of the breech cap sleeve **152** and the lock pin **179**

may be mounted directly on and operatively engaged by the threads **197** in a manner corresponding to that described above and illustrated for the pin guide housing **170**.

With reference to **Figure 11**, the cartridge **30** may be a cartridge of any suitable design and construction. Suitable cartridges are available from Tyco Electronics, Inc. The cartridge **30** as illustrated includes a shell **34** having a side wall **34A**, an end wall **34B**, and a radially outwardly extending flange **34C**, and defining a shell cavity **34D**. A quantity of primer **36** and the main charge **32** are disposed in the shell cavity **34D**. The primer **36** may be, for example, a quantity of nitroglycerin packaged in a cap or the like. The charge **32** may be, for example, a quantity of gun powder or other suitable propellant . The charge **32** is separated from the primer by a gas check **39**. The gas check has upstanding prongs **39A**. The cartridge may be formed of a polymeric material such as polyethylene, for example.

With reference to **Figure 1**, the tool head **80** includes an abutment **82**, a driver mount portion **84**, and a cradle **88** defined therebetween. A threaded coupling bore **86** is formed in the driver mount portion **84**. The tool head **80** is exemplary, and any suitable tool head may be employed.

The foregoing components may be formed of any suitable materials. According to some embodiments, with the exception of the cartridge **30**, all of the components are preferably formed of metal and, more preferably, steel of appropriate strength and hardness.

The tool assembly **40** may be used to form the connection **5** in the following manner. For the purposes of explanation, the procedure will be described starting with an initially open configuration wherein no cartridge **30** is installed in the drive assembly **100** and the drive assembly is in the open position. It will be appreciated from the description herein that certain of the steps discussed below can be revised in order.

The connection **5** may be temporarily formed by installing the sleeve **22** on and about the conductors **7**, **9**, and forcing the wedge **24** into the sleeve **22** by hand or using a hammer.

When the drive assembly **100** is in the open position as shown in **Figure 6**, the breech cap assembly **150** is located such that it does not cover the breech opening **108B**. The pin guide housing **170** and the gas release knob **190** are each

unscrewed or backed out to respective open positions as shown in **Figure 10**. Accordingly, the piercer pin **184** is retracted with respect to the pin guide **180**.

According to some embodiments, it is preferable to load the tool **45** with the tool vertically oriented such that the coupling points upwardly. In order to maintain the breech cap assembly **150** in the open position, an edge of the breech cap sleeve **152** may be inserted into the support recess **144** whereby the breech cap assembly **150** is supported. Such a configuration, which is shown in **Figure 6**, allows the user to use one hand to hold the tool **45** and the other hand to hold the cartridge **30** while the breech cap assembly **150** remains properly positioned.

The cartridge **30** is inserted into the breech chamber **106** through the breech opening **108B**. In doing so, the ram **70** is inserted into the forward portion of the shell cavity **38** such that the driven end **74** of the ram is positioned above the primer **36** but separated therefrom by the prongs **39A**. According to some embodiments, the shell **34** is sized such that it will be temporarily retained in the opening **134B** by a moderate friction fit. The shell **34** may include compressible ribs on its outer surface for this purpose.

With the cartridge **30** in place, the breech cap assembly **150** is lifted from the support recess **144** and slid downwardly parallel to a slide axis **S-S** a short distance to assume the position illustrated in **Figure 7**. The breech cap assembly **150** is then pivoted about the tabs **167** about a pivot axis **P-P** in a direction **B**. The breech cap assembly **150** is pivoted into a position as shown in **Figure 8**, wherein the breech cap assembly **150** is substantially coaxial with the breech **102**. It will be appreciated that the pivoting path may not be restricted to pivoting about a single point, but may instead by somewhat accurate, for example.

The breech cap sleeve **152** is then pushed forward on the breech **102** along the slide axis **S-S** in a direction **D**. The slide axis **S-S** is transverse (and, according to some preferred embodiments, perpendicular) to the pivot axis **P-P**. The tabs **167** slide within the axially extending channels **114A, 114B** to thereby guide the breech cap sleeve **152** with respect to the breech **102**. The breech cap sleeve **152** is slid onto the breech **102** until the breech cap assembly **150** reaches the position as shown in **Figure 9**. This movement will serve to push the cartridge **30** fully into the breech **106** until the flange **34C** abuts the flange **136** of the ejector sleeve **130** if the cartridge **30** is not already so positioned.

The breech cap sleeve **152** is then rotated relative to the breech **102** about the slide axis **S-S** in a rotational direction **E** (**Figure 9**). The tabs **167** slide within the circumferentially extending channels **116A, 116B** to thereby guide the breech cap sleeve **152** with respect to the breech **102**. The breech cap sleeve **152** is rotated in this manner on the breech **102** until the breech cap sleeve **152** reaches the position as shown in **Figures 2** and **10**. In this position, the tabs **167** and the circumferentially extending channels **116A, 116B** cooperate to prevent relative movement between the breech cap sleeve **152** and the breech **102** along the axis **S-S**.

The pin guide housing **170** may then be rotated in a direction **F** (**Figure 9**) about the axis **S-S** to screw the pin guide housing **170** into the breech cap sleeve **152** and closer to the breech **102**. The threads **178** slide within the cutout **179A** of the lock pin **179** so that the lock pin **179** does not rotate but is driven forwardly through the slot **158** into the lock pin recess **142**. The pin guide housing **170** is screwed into the breech cap sleeve **152** until the forward end of the pin guide housing **170** engages the ejector sleeve **130** and forces the ejector sleeve forwardly against the breech **102**. The resulting position is shown in **Figure 11**. In this position, the breech cap sleeve **152** is prevented from rotating relative to the breech **102** by the engagement between the lock pin **179** and the ejector sleeve **130**. Additionally, according to some embodiments the cartridge **30** is driven forward by the housing **170** such that the prongs **39A** are crushed by the ram **70**.

The gas release knob **190** is then rotated in a direction **G** (**Figure 9**) about the axis **S-S** to screw the gas release knob **190** into the pin guide housing **170** and closer to the breech **102** until the gas release knob **190** reaches a sealing position as shown in **Figure 12**. In this manner, the piercer pin **184** is forced forwardly such that it pierces and the end wall **34B** of the cartridge **30**. The piercer pin **184** remains in the end wall **34B** to seal the hole in the end wall **34B** thus formed.

Using an alternative sequence, the housing **170** may not be screwed into the breech cap sleeve **152** as described above prior to rotating the gas release knob **190.** Instead, the gas release knob **190** is first rotated in the direction **G**. The rotation of the gas release knob **190** will also rotate the housing **170** into the proper position after the gas release knob **190** has reached the proper position in relation to the housing **170**. More particularly, at this time, the stop screw **199** will engage the tab **177**, thereby causing the housing **170** to rotate with the gas release knob

190. The gas release knob **190** and the housing **170** will continue to turn together until the forward end of the housing **170** engages the ejector sleeve **130.** With the lock pin **179** and the ejector sleeve **130** interlocked in this manner, the breech cap sleeve **152** cannot be rotated relative to the breech **102** about the slide axis **S-S.** This procedure for rotating the housing **170** and the knob **190** may be more convenient for execution by the operator.

The breech cap assembly **150** is now in the closed position as shown in **Figures 2** and **12**. In this position, the rear breech opening **108B** is covered by the breech cap assembly **150** and thereby effectively sealed. The front end opening **108A** is substantially sealed by the ram **70.** The ram **70** is positioned such that its forward end is substantially flush with the forward opening of the coupling **50**. According to some embodiments, the prongs **39A** may be partially crushed by the rear end of the ram **70**; however, the strike pin **76** is spaced apart from the primer **36**. A small gap **78** (**Figure 10**) is defined between the coupling **50** and the breech **102** in the coupling nut **60**. The tool **45** is now prepared for firing.

Prior to or following loading of the cartridge **30** as described above, the coupling **50** of the tool assembly **40** is screwed into the coupling bore **86** of the tool head **80** such that sufficient spacing between the front end of the coupling **50** and the abutment **86** remains for inserting the sleeve **7** and the wedge **9**. The tool assembly **40** thus formed is then installed about the sleeve **7** and the wedge **9** as shown in **Figure 1** such that the components **7**, **9** are received in the cradle **88**. The coupling is screwed into the bore **86** until the sleeve **22** abuts the abutment **82** and the forward end of the coupling **50** abuts the wedge **24**.

With the tool assembly **40** prepared and positioned as described above, the user next strikes the end wall **191** of the gas release knob **190**. The gas release knob **190** may be struck using a hammer **15** (**Figure 1**), for example. The strike force may be directed generally along the axis **S-S**. By striking in this manner, the user forces the coupling **50** against the wedge **24**, which in turn slides the coupling **50** rearward in the coupling nut **60** to close the gap **78** (**Figure 10**). The ram **70** is also thereby driven back into the cartridge **30** and the breech **102** such that the firing pin **76** is thereby driven into contact with the primer **36** to ignite the primer **36**. The primer **36** in turn ignites the main charge **32**. The explosion of the main charge **32** is contained by the closed breech **102** so that the ram **70** is driven

forwardly by the explosion and forces the wedge **24** into the sleeve **22**, thereby forming the connection **5**.

The fired cartridge **30** can be removed and the tool **40** reloaded with a fresh cartridge using the following procedure. Typically, following the firing of the cartridge **30**, a pressurized gas from the exploded charge **32** will remain in the breech chamber **106**. Immediately removing the breech cap sleeve **152** from the breech **102** may cause the gas to be released in a manner potentially harmful to the user, bystanders, or the tool itself. Thus, it is desirable to first pre-release the gas in a controlled fashion. To accomplish this, the gas release knob **190** is rotated in a direction **H** (**Figure 9**) about the axis **S-S** to unscrew the gas release knob **190** from the pin guide housing **170** to the gas release position as shown in **Figure 11**. In this manner, the piercer pin **184** is pulled rearwardly such that it is withdrawn from the end wall **34B** of the cartridge **30**. The pressurized gas trapped in the breech chamber **106** and the cartridge **30** is allowed to escape through the hole in the end wall **34B**, the bore **182** in the pin guide **180**, and the gas release passage **196** in the gas release knob **190**.

The user then continues to rotate the gas release knob **190** in the direction **H** such that the stop screw **199** engages the tab **177** and causes the pin guide housing **170** to rotate in the direction **H** with the gas release knob **190**. The rotation of the housing **170** causes the housing **170** to translate rearwardly along the axis **S-S**, thereby withdrawing the locking pin **179** from the locking pin recess **142**, and placing the drive assembly **100** in the position shown in **Figure 10**. According to some embodiments, the stop screw **199** will engage and begin rotating the housing **170** after the gas release knob **190** has been rotated less than 360 degrees.

The breech cap sleeve **152** is thereafter rotated relative to the breech **102** in a direction I (**Figure 9**) about the axis **S-S** to align the tabs **167** with the axially extending channels **114A, 114B**, as shown in **Figure 9**.

The breech cap sleeve **152** is then slid (*e.g.*, pulled) relative to the breech **102** in a direction **J** (**Figure 8**) along the axis **S-S** with the axially extending channels **114A, 114B** serving to guide the breech cap sleeve **152**. The breech cap sleeve **152** is slid such that the tabs **167** engage the ejector sleeve **130** and force the ejector sleeve **130** rearwardly relative to the breech **102**. In this manner, the

cartridge **30** may be dislodged from the breech **102**. The user may grasp and pull the ejector sleeve **130** using the ribs **146** to facilitate removal of the cartridge.

The breech cap assembly **150** is next pivoted about the axis **P-P** in a direction **K (Figure 8)**. In this manner, the breech cap assembly **150** is returned to the open position as shown in **Figure 7**. The breech cap assembly **150** may be further lifted to the supported position of **Figure 6**. The spent cartridge **30** is now partially exposed and dislodged and can be easily removed and discarded. After the cartridge **30** has been removed, a new cartridge can be inserted into the drive assembly **100** and the tool **45** again prepared and fired in the manner described above.

The tool assembly **40** according to the present invention may provide a number of advantages. Because the drive assembly **100** is one integral or interconnected unit, it can be conveniently loaded and unloaded. In particular, it is not necessary to remove the breech cap assembly **150** or any portion thereof to access the breech chamber **102**. Nonetheless, when the breech cap assembly **152** is in the open position, the breech opening **108B** can be fully exposed to allow easy and effective insertion or removal of the cartridge. The drive assembly **100** may provide an effective, durable and reliable mechanism for safely releasing pressurized gas from the breech chamber **106** prior to opening the breech cap assembly **150**. Moreover, according to some embodiments including those illustrated in the figures, the drive assembly **100** requires that the gas release knob **190** be axially withdrawn relative to the breech **102** in order to withdraw the locking pin **179** before the breech cap sleeve **152** can be rotated relative to the breech **102**. This required sequence ensures that the piercer pin **184** will first be withdrawn from the cartridge, thereby ensuring that any pressurized gas will be released before the breech cap sleeve **152** is removed from its interlock with the circumferentially extending channels **116A, 116B.**

While the drive assembly **100** includes the rotatable housing **170** and the separately rotatable gas release knob **190**, in accordance with other embodiments of the invention the housing and the gas release knob may be integrally formed or assembled. However, the separately rotatable housing and gas release knob of the drive assembly **100** may provide enhanced safety and convenience. For example, the drive assembly **100** allows for release of pressurized gas by retracting the gas

release knob **190** while still maintaining the breech cap sleeve **152** and the cartridge **30** in a secure arrangement by means of the housing **170**.

As will be appreciated by those of skill in the art upon reading the description herein, the drive assembly **100** and other drive assemblies in accordance with the present invention may be used with explosive charge-actuated tools of other designs.

The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. Therefore, it is to be understood that the foregoing is illustrative of the present invention and is not to be construed as limited to the specific embodiments disclosed, and that modifications to the disclosed embodiments, as well as other embodiments, are intended to be included within the scope of the appended claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.